Original Research Communications—general

Cigarette smoking, dietary intake, and physical activity: effects on body fat distribution—the Normative Aging Study[1-3]

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ABSTRACT Studies have indicated that although smokers weigh less than nonsmokers, smokers have greater waist-to-hip circumference ratios after adjustment for age and body mass index (BMI). The purpose of this investigation was to determine whether factors associated with smoking, such as dietary intake, alcohol intake, and physical activity, modified or confounded the relationship between smoking and body fat distribution. The study used cross-sectional data for 765 men aged 43–85 y from the Normative Aging Study. Current smokers were found to have a greater amount of central adiposity, as represented by the abdomen-to-hip circumference ratio (abdomen-hip ratio), than did former smokers and people who never smoked after adjustment for age, BMI, dietary and alcohol intakes, and physical activity. Multiple-linear-regression analysis revealed that physical activity was negatively associated with and alcohol intake was positively associated with the abdomen-hip ratio. These results suggest a direct effect of smoking on body fat distribution, independent of other smoking-related behaviors. *Am J Clin Nutr* 1991;53:1104–11.

KEY WORDS Body fat distribution, cigarette smoking, alcohol, dietary intake, physical activity

Introduction

The effect of cigarette smoking on body weight is well documented (1–10). In general, smokers weigh less than nonsmokers (1–8) in all age groups (9) and former smokers gain weight after cessation of smoking (1, 3, 5, 7, 10). Whether the distribution of body fat (with relative weight controlled for) differs by smoking status is less clear. Because the degree of overall adiposity has been shown to have a positive correlation with centripetal fat distribution (11–14), smokers, because of their lower weights, might be expected to have a lower proportion of central adiposity than peripheral adiposity. Investigators, however, have found contradictory results (5, 6): although smokers weighed significantly less than nonsmokers, the waist-to-hip ratio (a measure of central adiposity), adjusted for age and body mass index (BMI), was significantly higher in smokers than in nonsmokers. Apart from BMI and age, factors that may influence the smoking-habitus relationship have not been well delineated. These include differences among smoking groups in dietary intake (including intake of alcohol and caffeine) and physical activity.

Research conducted on the smoking-habitus relationship may have important implications for an understanding of the increased risk of development of several diseases in smokers and may provide additional information to clinicians and public health educators that will encourage smokers to quit. Body fat distribution has been shown to be an important risk factor for diabetes (15–21) and cardiovascular disease (20, 22–24). Thus, cessation of smoking may result in the modification of disease risk directly (through cessation itself) and indirectly (through a change in habitus).

The purpose of this investigation was to determine the relationship between smoking and habitus, with adjustments for dietary intake and physical activity. In addition, the influence of dietary intake and physical activity on body fat distribution was assessed.

Subjects and methods

The Normative Aging Study is an ongoing longitudinal, multidisciplinary study established by the Veterans Administration in 1961. Details of the study protocol were presented elsewhere (25). Male volunteers were screened for a variety of medical conditions, including hypertension, cancer, and diabetes, to identify an initially healthy population. Body weight and hyperlipidemia were not screening criteria. Subjects have received biomedical and anthropometric examinations every 3–5 y since 1961.

Anthropometric measurements (1, 26) are made with the subject in undershorts and socks. Weight is measured on a balance-

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[2] Supported by grant HL37871 from the Division of the Heart, Lung, and Blood Institute and VAO3 from the Medical Research Service of the Department of Veterans Affairs.

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Received March 27, 1990.
Accepted for publication September 5, 1990.

beam scale to the nearest 0.5 pound and converted to kilograms. Stature is measured against a wall chart to the nearest 0.1 inch and converted to meters. BMI was calculated as weight (kg) divided by height (m) squared. With this calculation BMI proved to be highly correlated with weight (age-adjusted $r = 0.87$, $P = 0.0001$) and uncorrelated with stature (age-adjusted $r = -0.05$, $P = 0.1039$). Abdomen circumference is measured in centimeters at the level of the umbilicus, perpendicular to the axis of the upper body. Hip circumference is measured at the greatest protrusion of the gluteal muscles. The ratio of abdomen circumference to hip circumference (abdomen-hip ratio) is then calculated.

Data on dietary intake are obtained by means of a semiquantitative food frequency questionnaire (27, 28). Subjects are mailed the questionnaire and asked to complete it before their visit to the study. Each questionnaire is independently coded by three researchers. A nutritionist who was involved in the development of the food frequency questionnaire is consulted when coding is found to be inconsistent among the three coders. The food frequency questionnaire lists food items with serving sizes and elicits information on frequency of intake. Nutrient scores are computed by multiplying the frequency of intake by the nutrient content of the food item. Values for macronutrient intake (protein, carbohydrate, and fat) and total dietary intake of alcohol, caffeine, sucrose, fiber, and calories are also derived from the food frequency questionnaire. A detailed description of the semiquantitative food frequency questionnaire was published elsewhere (27, 28). Complex carbohydrates are defined as the difference between total carbohydrates and sucrose. Nutrient densities for total fat, saturated fatty acids, total carbohydrate, complex carbohydrate, protein, and sucrose were computed by expressing the macronutrient as a percentage of caloric intake. This procedure was used to adjust for total caloric intake while preserving a meaningful value for the macronutrient. Values for alcohol, caffeine, and fiber intake were adjusted for total caloric intake by regression analysis. The food frequency questionnaire also provides information on physical activity. On the basis of the scale of Paffenbarger et al (29), questions on the number of flights of stairs climbed per day, walking pace, and the frequency of various physical activities were used to derive total kilocalories used per week. The distribution of kilocalories used per week was divided into three categories: light (< 1500 kcal/wk), moderate (1500–3500 kcal/wk), and heavy (> 3500 kcal/wk) physical activity.

Information on smoking status was collected by interview at the time of the participants' visit for an examination. Subjects were categorized as people who never smoked (never-smokers), current smokers, or former smokers on the basis of their self-reported status on the day of their exam. In addition, the number of cigarettes smoked per day, the amount of the cigarette smoked (more than three-fourths, about three-fourths, ~one-half, < one-half), and the depth of inhalation (inhaled as far into the chest as possible, inhaled as far as the chest, inhaled as far as the throat, puffed only) were available for current smokers.

Data were collected from examinations conducted between February 1987 and May 1989. Seven food frequency questionnaires with values for total caloric intake that fell outside the range of 600–4500 kcal/d were considered to represent under- or overreporting and were excluded from the analyses. Anthropometric measurements, smoking information, and data on dietary intake and physical activity were available for 765 subjects (aged 43–85 y) from a total of 889 subjects examined during this period. The present study included these 765 subjects. An analysis of subjects not included in the present study ($n = 124$) showed differences in stature and smoking status. The excluded subjects were significantly shorter, on average, than were the study subjects ($\bar{x}$ stature ± SD = 172.69 ± 8.8 vs 175.51 ± 6.5 cm) and there were more current smokers (19.19% vs 10.59%) and less never-smokers (25.25% vs 31.76%) in the group of excluded subjects than in the study sample. Values for age, weight, BMI, abdomen and hip circumference, abdomen-to-hip circumference ratio (abdomen-hip ratio), physical activity, and dietary intake did not differ significantly between the subjects excluded from the analyses and the subjects included in the analyses. The 35 subjects with missing dietary data (including the seven excluded on dietary assessment) also were compared with the 765 included subjects. Nonrespondents for dietary intake were significantly older (65.91 ± 9.43 vs 62.02 ± 7.99 y, $P = 0.0054$) and shorter (171.37 ± 8.14 vs 175.51 ± 6.55 cm, $P = 0.0015$) and had a significantly greater mean abdomen-hip ratio (1.00 ± 0.04 vs 0.97 ± 0.04, $P = 0.0132$). Smoking status was not different between the nonrespondents for dietary intake and the study subjects.

One-way analysis of variance was used to examine differences in age by smoking status. Analysis of covariance was used to compare age-adjusted means among smoking groups for dietary intake, physical activity, weight, stature, and BMI and to compare age- and BMI-adjusted means for abdomen-hip ratio, abdomen circumference, and hip circumference. Partial correlations adjusted for age and total caloric intake were calculated between the dietary-intake variables and both the abdomen-hip ratio and BMI. In current smokers, Pearson product-moment correlations were calculated between cigarettes smoked per day and both the abdomen-hip ratio and BMI. Analysis of covariance also was used to compare age-adjusted means for BMI and age- and BMI-adjusted means for abdomen-hip ratio among physical-activity categories. The effect of cigarette smoking on the abdomen-hip ratio was evaluated by multiple-linear-regression analyses after the effects of dietary intake, BMI, age, and physical activity were controlled for. In current smokers only, analysis of covariance and multiple-linear-regression analysis was used to determine the effect of cigarettes per day on the abdomen-hip ratio.

The natural logarithms for BMI, weight, abdomen circumference, hip circumference, and alcohol intake were used to improve the linearity assumption in the general linear models and regression analyses. The exponents of the unadjusted and adjusted least-square means and confidence intervals for the logarithm-transformed variables were tabulated to facilitate interpretation of the comparisons. All statistical analyses were performed by means of the Statistical Analysis System (*SAS*) *AOS/VS* version 5.18 (30) and *UNIX* version 6.03.

Results

Former smokers made up 58.7% of the sample ($n = 449$), 30.7% were never-smokers ($n = 235$) and only 10.6% were current smokers ($n = 81$). Quit time, the average quit length for former smokers, was 19.45 ± 11.75 y. Cessation for 95% of former smokers was ≥ 2 y ago. Smoking status was related to age ($P = 0.0001$): never-smokers were the oldest (63.75 ± 8.42 y), former smokers the next oldest (61.81 ± 7.61 y), and current

TABLE 1
Adjusted least-square means (confidence intervals) of anthropometric variables, by smoking status

Variable	1 Never-smokers (n = 235)	2 Former smokers (n = 449)	3 Current smokers (n = 81)
Adjusted for age			
Weight (kg)	80.44 (79.04, 81.85)	82.50 (81.53, 83.42)*	79.42 (76.93, 81.94)†
Height (cm)	174.75 (173.94, 175.55)	175.76 (175.17, 176.34)*	176.27 (174.88, 177.65)
BMI‡	26.37 (25.97, 26.78)	26.73 (26.41, 27.03)	25.60 (24.90, 26.31)§
Adjusted for age and BMI			
Abdomen circumference (cm)	99.85 (99.28, 100.28)	100.29 (99.88, 100.68)	101.37 (100.38, 102.30)*
Hip circumference (cm)	102.62 (102.20, 103.02)	102.65 (102.41, 102.82)	102.57 (101.69, 103.33)
Abdomen-hip ratio	0.9740 (0.9701, 0.9779)	0.9781 (0.9762, 0.9800)	0.9894 (0.9816, 0.9972)†‖

*‖ Significantly different from never-smokers: *$P < 0.05$, ‖$P < 0.01$.
†§ Significantly different from former smokers: †$P < 0.05$, §$P < 0.01$.
‡ Body mass index, expressed in kg/m^2.

smokers the youngest (58.21 ± 7.44 y). Current smokers smoked an average of 25 cigarettes/day, ranging from 0 (one subject reported being an occasional smoker and averaged < 1 cigarette/d but > 1 cigarette/wk) to 60 cigarettes/day. The vast majority of smokers (n = 57, 75%) reported smoking more than three-fourths of the cigarette, 14 subjects (18.4%) reported smoking about three-fourths, and five subjects (6.6%) reported smoking about one-half of the cigarette. None of the subjects reported smoking less than one-half of the cigarette. Most of the smokers reported inhaling as deeply into the chest as possible (n = 60, 78.9%); eight subjects (10.5%) reported inhaling as far as the chest, seven subjects (9.2%) reported inhaling as far as the throat, and one subject (1.3%) reported that he puffed only. Five subjects had missing values for the amount of the cigarette smoked and depth of inhalation.

Table 1 describes the anthropometric characteristics of the sample, by smoking group. The relationships between smoking status and the anthropometric measurements are adjusted for age. As expected, current smokers weighed less and had a lower mean BMI than did either never-smokers or former smokers. Because the abdomen-hip ratio was highly correlated with BMI in this sample (r = 0.45, P = 0.0001), the relationships of smoking to the abdomen-hip ratio, abdomen circumference, and hip circumference were adjusted for BMI in addition to age. The ratio of abdomen-to-hip circumference, adjusted for age and BMI was greater in current smokers than in either former smokers or never-smokers. Current smokers also had a larger mean abdomen circumference than did never-smokers. There were no statistically significant differences in hip circumference after adjustment for age and BMI among smoking groups.

Table 2 describes dietary intake, by smoking group. The comparisons are adjusted for age. Total caloric intake was not significantly different among smoking groups (P = 0.1899); however, there were differences in dietary composition by smoking group. Current smokers derived significantly more calories from saturated fatty acids and fewer calories from total and complex carbohydrates than did former smokers and never-smokers. Dietary intake of alcohol, caffeine, and fiber also differed by smok-

TABLE 2
Least-square means (confidence intervals) of dietary intake variables, by smoking status, adjusted for age and total calories

Variable	Never-smokers (n = 235)	Former smokers (n = 449)	Current smokers (n = 81)
Total calories (kcal/d)	1932.53 (1849.43, 2015.63)	2010.13 (1950.45, 2069.81)	2067.11 (1924.86, 2209.36)
Total fat (% of total kcal)	30.37 (29.79, 30.95)	30.33 (29.94, 30.72)	31.38 (30.21, 32.55)
Saturated fatty acids (% of total kcal)	23.97 (23.13, 24.80)	24.20 (23.58, 24.81)	26.15 (24.69, 27.60)*†
Total carbohydrates (% of total kcal)	51.04 (50.06, 52.02)	49.19 (48.41, 49.97)‡	45.90 (44.14, 47.66)§‖
Complex carbohydrates (% of total kcal)	40.61 (39.83, 41.39)	39.27 (38.69, 39.85)¶	36.11 (34.74, 37.48)§**
Sucrose (% of total kcal)	10.43 (10.04, 10.82)	9.91 (9.52, 10.30)	9.79 (9.01, 10.57)
Protein (% of total kcal)	16.48 (16.09, 16.87)	16.30 (16.11, 16.49)	15.82 (15.24, 16.40)
Dietary fiber (g)	21.54 (20.64, 22.43)	20.47 (19.82, 21.11)	16.51 (14.97, 18.04)§**
Caffeine (mg)	242.95 (216.55, 269.35)	289.76 (270.83, 308.69)‡	375.34 (330.17, 420.51)§†
Alcohol (g)	5.53 (4.64, 6.58)	8.33 (7.35, 9.45)*	11.93 (8.86, 16.08)§††

*‡§¶ Significantly different from never-smokers: *$P < 0.001$, ‡$P < 0.01$, §$P = 0.0001$, ¶$P < 0.05$.
†‖**†† Significantly different from former smokers: †$P < 0.001$, ‖$P < 0.01$, **$P < 0.0001$, ††$P < 0.05$.

TABLE 3
Partial correlations, adjusted for age and total caloric intake, between dietary intake variables and both the abdomen-hip ratio and body mass index (BMI)*

	Total fat	Saturated fatty acids	Total carbohydrates	Complex carbohydrates	Protein	Fiber	Alcohol
Abdomen-hip ratio	0.06	0.10	−0.11	−0.12	−0.02	−0.13	0.07
p	0.0989	0.0083	0.0028	0.0013	0.5046	0.0002	0.0521
BMI	0.17	0.17	−0.13	−0.14	0.08	−0.11	−0.04
p	0.0001	0.0001	0.0005	0.0002	0.0341	0.0021	0.2196

* Correlations with intake of total calories, sucrose, and caffeine were not statistically significant with BMI or the abdomen-hip ratio and are not shown.

ing group. Independent of total caloric intake, current smokers had a higher mean intake of alcohol and caffeine and a lower dietary intake of fiber than did former smokers and never-smokers. Intake of sucrose and calories derived from total fat or protein were not significantly different among smoking groups.

Partial correlations adjusted for age (**Table 3**) revealed weak but statistically significant relationships between the abdomen-hip ratio and the percentage of daily caloric intake derived from saturated fatty acids ($r = 0.10$, $P = 0.0083$), total carbohydrates ($r = -0.11$, $P = 0.0028$), and complex carbohydrates ($r = -0.12$, $P = 0.0013$). Independent of total calories, dietary fiber intake was negatively correlated with the abdomen-hip ratio ($r = -0.13$, $P = 0.0002$), and a correlation of borderline significance was observed between the abdomen-hip ratio and alcohol intake ($r = 0.07$, $P = 0.0521$). Total caloric intake, calories derived from total fat and protein, and caffeine and sucrose intakes were not significantly correlated with the abdomen-hip ratio. The nutrient densities were more highly correlated with BMI than with the abdomen-hip ratio. BMI was positively correlated with calories derived from total fat ($r = 0.17$, $P = 0.0001$), saturated fatty acids ($r = 0.17$, $P = 0.0001$), and protein ($r = 0.08$, $P = 0.0341$) and was negatively correlated with calories derived from total carbohydrates ($r = -0.13$, $P = 0.0005$) and complex carbohydrates ($r = -0.14$, $P = 0.0002$). The correlation between BMI and dietary fiber ($r = -0.11$, $P = 0.0021$), independent of total caloric intake, was also significant. Total caloric intake, the nutrient density for sucrose, and alcohol and caffeine intakes (adjusted for total caloric intake) were not significantly correlated with BMI.

Unadjusted correlations of number of cigarettes smoked per day with BMI and the abdomen-hip ratio were not statistically significant ($r = -0.03$, $P = 0.7844$; $r = 0.14$, $P = 0.2217$, respectively). When cigarettes smoked per day was divided into tertiles, abdomen-hip ratio was significantly greater in subjects smoking 36–60 cigarettes/d than in subjects smoking 20–30 cigarettes/d and 0–18 cigarettes/d (abdomen-hip ratio 1.00 + 0.009 vs 0.9764 + 0.007 ($\bar{x} \pm$ SEM), $P = 0.0243$ and 0.9755 ± 0.009, $P = 0.0352$) after adjustment for age and BMI.

Table 4 presents values for BMI and abdomen-hip ratio, by physical-activity category. BMI was inversely related to level of physical activity. After controlling for age, the mean BMI for subjects in the heavy-physical-activity category was lower than the mean BMI for subjects in the moderate-activity category; this value was in turn lower than the mean BMI for subjects in the light-activity category. The abdomen-hip ratio was also inversely related to physical activity. After controlling for age and BMI, the mean abdomen-hip ratio for subjects in the heavy-physical-activity category was significantly lower than the mean abdomen-hip ratio for subjects in both the moderate- and the light-physical-activity categories. Smoking status was not associated with degree of physical activity ($P = 0.8663$, results not shown).

Multiple linear regression was used to determine if the abdomen-hip ratio remained greater in current smokers after controlling for the other covariates. The basic regression model included age, BMI, and physical activity. The regressions were modeled separately for each of the nutrient-density variables because of the high degree of multicollinearity among them. (Correlations ranged from $r = -0.13$ to $r = -0.63$ among the nutrient densities.) Alcohol, caffeine, dietary fiber, and total calories were also modeled separately. Results of the regression analyses with the abdomen-hip ratio as the dependent variable revealed a positive and significant regression coefficient for current smoking in all of the models. Physical activity was also a significant negative predictor of the abdomen-hip ratio. None of the dietary variables except alcohol intake remained inde-

TABLE 4
Adjusted means (confidence intervals) of BMI and abdomen-hip ratio, by physical-activity category*

Variable	Light ($n = 445$)	Moderate ($n = 247$)	Heavy ($n = 73$)
BMI	26.99 (26.68, 27.31)	26.09 (25.69, 26.50)†	24.98 (24.30, 25.67)‡§
Abdomen-hip ratio	0.9815 (0.9776, 0.9854)	0.9758 (0.9719, 0.9797)	0.9645 (0.9547, 0.9743)‖¶

* BMI is adjusted for age, and abdomen-hip ratio is adjusted for age and BMI.
†‡‖ Significantly different from light: †$P < 0.001$, ‡$P = 0.0001$, ‖$P < 0.01$.
§¶ Significantly different from moderate: §$P < 0.05$, ¶$P < 0.05$.

pendently related to the abdomen-hip ratio (data not shown). Regression models with and without alcohol intake are presented in **Table 5**. With alcohol in the model, the regression coefficient for current smoking decreased by 15% but remained statistically significant.

The inclusion of cigarettes smoked per day in a multiple-regression model incorporating data only from current smokers did not add significantly to the explained variance in abdomen-hip ratio (data not shown).

The possibility that cigarette smoking and alcohol intake might exert a synergistic effect on the abdomen-hip ratio was assessed in a separate regression model that included age, BMI, and physical activity, the main-effect terms for smoking and alcohol intake, and a term to represent the interaction of smoking and alcohol intakes. Neither the main-effect terms nor the interaction terms were statistically significant.

Discussion

The effect of cigarette smoking on body fat distribution was assessed cross-sectionally in 765 men. Current smokers had a greater mean abdomen-hip ratio than did former smokers and never-smokers, independent of age and BMI. After controlling for the effects of dietary intake and physical activity, the abdomen-hip ratio remained greater in current smokers. Multiple-linear-regression analyses revealed that in addition to smoking, physical activity and alcohol intake were independently associated with central adiposity as represented by the abdomen-hip ratio.

Our results agree with those of Haffner et al (11), who reported a positive relationship between smoking and waist-to-hip ratio independent of age, BMI, and sex. Studies by Shimokata et al (6) and by Barrett-Connor and Khaw (7) substantiated these results in men and women, respectively. Because abdomen circumference was used instead of waist circumference as a measure of central adiposity in this study, our values for abdomen-hip ratio are slightly higher than those presented in the papers of Shimokata et al and Barrett-Connor and Khaw. However, the magnitude of the differences in the ratio adjusted for age and BMI among smoking groups in all three studies is similar (the increase in the ratio from never-smokers or nonsmokers to current smokers ranges from 1.3% to 1.7%) and somewhat modest. Smokers in the highest tertile of cigarettes smoked per day had significantly greater abdomen-hip ratios than did smokers in either the middle or lowest tertile of cigarettes smoked per day. It was not possible to assess the effects of the amount of the cigarette smoked and depth of inhalation on the abdomen-hip ratio because smokers in this sample were homogeneous with respect to these two variables. The present study adds to previous findings by demonstrating that the effect of smoking on the waist-to-hip ratio may be independent of physical activity, dietary intake, and alcohol intake.

Our finding of differences in macronutrient intake between smokers and never-smokers—specifically, a greater intake of saturated fatty acids and a lower intake of fiber, total carbohydrates, and complex carbohydrates in smokers—seems plausible because smokers may be less concerned with maintaining a healthy diet. Studies of macronutrient intake as related to smoking status, however, have provided equivocal results (5, 10, 31–34). Total caloric intake was not significantly different among the smoking groups in this investigation and is thus unlikely to have influenced the observed macronutrient relationships with smoking; nonetheless, the values obtained were adjusted for total caloric intake.

Although differences in dietary intake of macronutrients were demonstrated among smoking groups, our data suggest that the positive association of smoking with central adiposity is independent of these differences. After adjustment for BMI, macronutrient intake had no demonstrable effect on the abdomen-hip ratio. Macronutrient intake was more highly correlated with BMI than with the abdomen-hip ratio in the unadjusted correlations. Perhaps this result indicates that an effect of macronutrients on central adiposity is mediated through overall adiposity. It would be worthwhile to reexamine this relationship in other studies.

Despite the finding of a positive association between current smoking and alcohol intake in this study [confirming other reports (3, 5)], both alcohol and smoking were independently related to the abdomen-hip ratio. Alcohol was weakly associated with the abdomen-hip ratio, independent of age, BMI, dietary intake, physical activity, and smoking. This same relationship was demonstrated by earlier data from the Normative Aging Study (35). On the contrary, Haffner et al (11) reported that alcohol intake was unrelated to the waist-to-hip ratio after adjustment for the effects of age, BMI, smoking, and physical activity. Despite this inconsistency in findings, the relationship of alcohol intake to increased centripetal obesity seems plausible. Casual observation reveals a propensity for alcohol users to de-

TABLE 5
The relationship of smoking to abdomen-hip ratio adjusted for age, BMI, and physical activity with and without adjustment for alcohol intake

	Without alcohol (R^2 = 0.22)			With alcohol (R^2 = 0.23)		
Independent variables	β	SEE (β)	P	β	SEE (β)	P
Age (y)	0.0002	0.0001	0.2073	0.0002	0.0001	0.1400
ln BMI	0.1582	0.011	0.0001	0.1590	0.011	0.0001
Physical activity (kcal/wk)	−0.0074	0.002	0.0014	−0.0077	0.002	0.0008
Smoking status						
Current vs never	0.0151	0.005	0.0059	0.0128	0.005	0.0203
Former vs never	0.0045	0.003	0.1747	0.0033	0.003	0.3215
Alcohol intake (g)	—	—	—	0.0027	0.001	0.0110

velop a beer gut or beer belly although the biological mechanism remains unclear.

Smokers had a lower mean relative weight compared with former smokers and never-smokers in this study. This observation has been well documented (1–9) but the reason smokers weigh less is still unclear. Many hypotheses have been posited to explain smokers' lower weights, including differences in dietary composition (34), bowel motility, and metabolic rate (10). Evidence supporting an increase in metabolism mediated by sympathetic-nervous-system activity has been provided by studies demonstrating an elevation in blood concentrations (36) and 24-h urinary excretion of norepinephrine in response to smoking (37). Resting metabolic rate as measured by indirect calorimetry also has been found to increase with nicotine intake (38).

Despite decreased relative adiposity in smokers, centripetal adiposity is increased. The mechanism by which smoking increases centripetal accumulation of body fat is unknown but at least one hypothesis has been proposed: an indirect effect of smoking on the distribution of body fat may be mediated through increased androgenicity (6), which may lead to increased accumulation of adipose tissue in the abdomen rather than in the femoral-gluteal area. Bjorntorp (39) suggested that endocrine milieu may control the direction of the distribution of excess body fat. Increased androgenic activity has been associated with an increased waist-to-hip ratio in obese (40) and nonobese (41) women, but these findings have not been substantiated in men.

Smoking appears to cause a masculinizing effect; biological indices that have been shown to be greater in males than in females also are greater in smokers. Smokers have higher low-density-lipoprotein (LDL) cholesterol (42), lower high-density-lipoprotein (HDL) cholesterol (43), and more accumulation of centripetal body fat (6, 7). Studies of the hormonal response to smoking, however, are inconsistent in men (44–48). Results, although inconclusive, appear to suggest that androgenic activity may not be increased in smokers (44–46, 48). Serum estradiol concentrations have been reported to be significantly higher in smokers than in nonsmokers, independent of age (44–46), relative body weight, physical activity (44, 46), alcohol intake (45, 46), and caffeine intake (46). On the other hand, data from the Multiple Risk Factor Intervention Trial (47) showed no association between smoking and serum estradiol or estrone concentrations. Plasma testosterone concentrations were reported to be lower in heavy smokers than in never-smokers matched for age, height, and weight, and a significant increase in testosterone concentrations in smokers was observed after a 7-d abstinence from smoking (48). Total and free testosterone were demonstrated to be increased in smokers, independent of age, relative weight, alcohol, blood pressure, and HDL cholesterol (47). Plasma testosterone concentration also was shown to be similar in smokers and nonsmokers (44). Further studies are needed to determine the role of hormones in the relationship between smoking and body fat distribution. In addition to measures of estrogen and testosterone, subsequent studies should include the ratio of androgens to estrogens and a measure of sex-hormone–binding globulin.

The ratio of abdomen-to-hip circumference was inversely related to physical activity, independent of age and BMI. These results agree with recent studies showing that physical activity may modify body fat distribution, independent of changes in BMI (49–51). Krotkiewski (49) reported a significant decrease in waist-to-hip ratio with and without reduction of body weight after 6 mo of physical training in premenopausal women. Despres et al (50) found a greater reduction in trunk skinfold thickness than in extremity skinfold thickness after a 20-wk, aerobic-exercise training program in nonobese men. Tremblay et al (51) found significantly lower waist-to-hip ratios in subjects performing high-intensity exercise even after adjustment for their lower subcutaneous skinfold thicknesses. Haffner et al (11) also found a negative association between physical activity and waist-to-hip ratio after adjustment for age, BMI, and smoking. In contrast, Shimokata et al (6) reported no correlation between maximal oxygen consumption on a treadmill or total caloric expenditure estimated from a physical-activity questionnaire and waist-to-hip ratio adjusted for age and BMI. It is conceivable that the type of physical activity (eg, aerobic conditioning vs nonaerobic weight training) might affect body fat distribution differentially. Additional research on the effect of physical activity on body fat distribution seems warranted by these studies.

Body fat distribution has been shown to be an important risk factor for diabetes (15–21). An increased risk of diabetes in persons with an accumulation of centripetal body fat was first reported by Vague (15); subsequent studies confirmed this association (16–18) and demonstrated relationships with glucose intolerance (19, 20) and hyperinsulinemia (20, 21). Body fat distribution has also been shown to be an important risk factor for cardiovascular disease (20, 22–24). An increased incidence of hypertension (22, 23), stroke (24), and ischemic heart disease (24) has been associated with an increased ratio of waist-to-hip circumference. The association between measures of centripetal-fat accumulation and cardiovascular risk was demonstrated to be independent of BMI in both men (22, 24) and women (20). These studies of the relationship of body fat distribution to chronic disease outcomes have not reported the specific consequence of adjusting for the effects of cigarette smoking. In the study of Larsson et al (24), adjusting for the effect of smoking actually improved the strength of the relationship of waist-to-hip ratio to mortality although the change in the coefficients was not reported. Adjustment for smoking did not affect the relationships of BMI, sum of skinfold thicknesses, and waist and hip circumference separately, to stroke, ischemic heart disease, and mortality. In the study of Lundgren (52), the relationship of waist-to-hip ratio to diabetes incidence remained significant after adjustment for smoking but the impact of the adjustment was not reported.

In summary, smoking was significantly related to central adiposity, as measured by the ratio of abdomen to hip circumference. This finding was independent of age, BMI, physical activity, and dietary and alcohol intakes. However, the magnitude of the relationship of smoking to the abdomen-hip ratio was modest, with an average increase of only 1.5% from never-smokers to current smokers. In addition to smoking, physical activity and alcohol intake were independent predictors of central adiposity. Body fat distribution has been identified as an important risk factor for cardiovascular disease and diabetes (15–24). The effects of behavioral factors such as smoking, dietary and alcohol intakes, and physical activity on body fat distribution are of clinical importance because they have the potential to be modified. Further investigation is essential to gain a better understanding of how these factors influence the distribution of body fat. ■

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